

Formal recognition of the species of the *Anopheles maculatus* group (Diptera: Culicidae) occurring in Thailand, including the descriptions of two new species and a preliminary key to females<sup>1</sup>

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**ABSTRACT.** The biological species currently known within the *Anopheles maculatus* group in Thailand are formally recognized. Descriptions are given for the adult and egg stages of *maculatus* Theobald, *willmori* James, *pseudowillmori* Theobald, *dravidicus* Christophers, *sawadwongporni* n. sp. and *notanandai* n. sp. The descriptions are based on an extensive study of progeny broods from wild-caught females that were identified from chromosomal rearrangements observed in their ovarian polytene chromosomes. Lectotypes are designated for *maculatus*, *willmori* and *dravidicus*. A preliminary key is provided for the identification of adult females.

The *Anopheles maculatus* group of species belongs to the *Neocellia* series of the subgenus *Cellia*. The group includes eight nominal forms: *maculatus* Theobald, 1901; *willmori* James, 1903; *indicus* Theobald, 1907; *dudgeonii* Theobald, 1907; *pseudowillmori* Theobald, 1910; *maculosa* James and Liston, 1911; *dravidicus* Christophers, 1924; and *hanabusai* Yamada, 1925. Theobald (1901) described *Anopheles maculatus* from specimens collected in Hong Kong. All of the other nominal forms, except *hanabusai*, were described from the Indian subcontinent (India and Pakistan). The nominal species of *hanabusai* was described from the island of Taiwan (Yamada, 1925).

Christophers (1931) regarded *maculatus* as a single species based on studies of morphological variation in adults. He recognized two varietal forms: one with reduced abdominal scaling, the nominotypical form; the other with heavy abdominal scaling, var. *willmori*. He considered *pseudowillmori*, *dravidicus*, and *hanabusai* as synonyms of the nominotypical form, and treated *dudgeonii*, *indicus*,

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and *maculosa* as synonyms of var. *willmori*. Despite notable studies on the adult and/or immature stages by Puri (1931), Christophers (1933), Crawford (1938); Reid et al (1966), and Reid (1968), the morphological concept and formal taxonomy of *maculatus* has remained unchanged.

The application of cytogenetics has permitted the recognition of six biological species (*sensu* Mayr, 1942) within the group in Thailand (Green, 1982; Green and Baimai, 1984; Green et al, 1985; Green et al, unpublished data). There is little doubt about the reality of these species since the evidence for their status rests upon population genetic data, collected directly from wild-caught specimens, which show absolute positive-assortative mating within groups marked by at least 18 paracentric inversions of the chromosomes. That is to say, individuals which are homozygous for one or the other alternative of these inversions occur together in nature in the total absence of heterozygotes. These six chromosomal groups (= biological species) have been informally designated with letters of the alphabet: species A, B, C (Green, 1982; Green et al, 1985); G (Green and Baimai, 1984); and species H and I (Green et al, unpublished data). Sympatric association of species A, B, C and G are known from a single locality (near Pakchong, Nakhon Ratchasima Province, Green, unpublished data); A, B, and G from near Phet Buri (Green and Baimai, 1984); A, B and C from several widely separated localities in western Thailand (Green et al, 1985); A, B and I from Mae Sariang, Mae Hong Son Province; B, H and I from Doi Inthanon, Chiang Mai Province; and B and H from Mae Sa, Chiang Mai Province (Green et al, unpublished data). Strictly speaking there is no direct population-genetic evidence for the relative status of A to H, or C and G to either H or I, but their chromosomal relationships suggest that they are not nearest relatives and so it is highly likely that they are distinct species.

*Anopheles beklemishevi* of the Palaearctic *maculipennis* group was formally recognized solely on the basis of chromosomal data similar to that collected for members of the *maculatus* group (Stegnii and Kabanova, 1976). This report is a more traditional, and probably more useful, approach to the formal recognition of genetically discovered species. Name-bearing types are fixed for two new species and morphological descriptions are provided for the differentiation of the adults of these and the four other members of the *maculatus* group occurring in Thailand.

#### MATERIALS AND METHODS

Morphological variation was investigated in wild-caught adults, adults (with associated larval and pupal exuviae) reared from wild-caught larvae, and adult progeny (with associated immature exuviae) from wild-caught females. Progeny broods were reared under relatively standard conditions of temperature and humidity in the laboratory and studied using the methods of Harrison (1980). A portion of fourth-instar larvae from each brood were killed for analysis of mitotic chromosomes. Ovarian polytene chromosomes were prepared from wild-caught females and the progeny of wild-caught females. Specimens were pinned for morphological study following the removal of ovaries. Once potentially diagnostic characters were gleaned from the literature and noted in specimens, they were checked in chromosomally identified progeny broods to ascertain their

distribution within and between broods. Those characters which bred true, i.e., were not mixed in single broods, were then analyzed for variability in wild-caught adults and adults reared from wild-caught larvae. Over 3,000 adults representing 464 broods were examined. Morphological variation was studied in more than 2,000 wild adults. The type specimens of all eight nominal forms of the group were critically examined following these studies.

Most methods of preserving anopheline eggs are unsatisfactory because they employ liquid preservatives. More often than not the exochorion, which often exhibits important taxonomic characters, is lost when eggs are stored in liquid. In this study, eggs were allowed to hatch, the chorions were collected on pieces of filter paper, and the paper was laid on dry paper to remove excess water. The eggs were then placed in a deep freeze and dehydrated by sublimation over a period of about one month. Many eggs retained their structural integrity, though some collapsed. They remained firmly attached to the filter paper. Ambient humidity, such as that encountered in Bangkok, may result in subsequent rehydration and deterioration of some eggs. The pieces of paper holding the eggs were placed on pins, with appropriate labels, and stored with their associated, pinned adults. It should be noted that the egg phenotype is determined by the maternal genotype and not by the genotype of the individual that emerged from the egg.

Major taxonomic and/or cytogenetic references are listed before the description of each species. Works which treat only the larval and pupal stages are not included. These and other pertinent references will be included in a comprehensive revision of the group in the Oriental Region.

The anatomical terminology used is that of Harrison and Scanlon (1975) and Harbach and Knight (1980). The abbreviations used for depositories are as follows: BM - British Museum (Natural History), London; IM - Zoological Survey of India, Indian Museum, Calcutta; IMS - Department of Parasitology, Institute of Medical Science, University of Tokyo, Tokyo; NICD - National Institute of Communicable Diseases, Delhi; NMNH - National Museum of Natural History, Smithsonian Institution, Washington, D.C. The drawings were made from several specimens.

*Anopheles (Cellia) maculatus* Theobald

**maculata** Theobald, 1901 (*Anopheles*).

**hanabusai** Yamada, 1925 (*Myzomyia*). Synonymy by Christophers, 1931.

*Nyssorhynchus maculatus* (Theobald) of James and Liston, 1911.

*Anopheles maculatus* Theobald of Christophers, 1931 (nominotypical form; in part); Christophers and Barraud, 1931 (E; in part); Reid et al, 1966 (A,L; in part).

*Anopheles (Myzomyia) maculatus* Theobald of Christophers, 1933 (♂,♀,P,L,E; in part); Bonne-Wepster and Swellengrebel, 1953 (♂,♀,L).

*Anopheles (Myzomyia) maculatus* var. *hanabusai* Yamada of Ho, 1938 ( $\sigma$ ,  $\varphi$ , P, L).  
*Anopheles (Cellia) maculatus* Theobald of Reid, 1968 ( $\sigma$ ,  $\varphi$ , P, L, E; in part).  
*Anopheles (Cellia) maculatus* B, E, and F of Green, 1982; Green and Baimai, 1984; Baimai et al, 1984; Green et al, 1985.

**Adult.** The nominotypical species is easily recognized and distinguished from the other members of the *maculatus* group by the general absence of scales on abdominal terga II-VI (a few pale falcate scales frequently occur on terga II and III) and the presence of more numerous and broader (spatulate) scales on terga VII and VIII. *Anopheles maculatus* could never be confused with *pseudowillmori* even though the number of scales on the abdominal terga are somewhat similar in the two species. Vein R<sub>2</sub> is distinctly shorter in *maculatus* than in *pseudowillmori*.

**FEMALE.** *Head* (Fig. 1A,C,D). Vertex with patch of erect white scales above interocular space, erect black scales laterally and on occiput; interocular space with frontal tuft comprised of 5 or 6 long pale yellow setae above and 9-16 very long white sinuous linear scales on each side; ocular scales white, falcate, broader laterally; clypeus dark, bare; pedicel of antenna light brown, with white falcate and/or spatulate scales in dorsolateral patch; antennal flagellomere 1 with black falcate scales at base on mesal and lateral surfaces, white falcate and spatulate scales on flagellomeres 1 and 2 and occasionally on base of flagellomere 3; proboscis entirely black-scaled, length 1.32-2.24 mm, ratio to length of forefemur 1.05 - 1.15; length of maxillary palpus 1.27-2.22 mm, ratio to proboscis length 0.88-1.00, with semierect black fusiform scales at base on palpomere 2, other scales decumbent, with narrow apical white band on palpomeres 2 and 3, palpomere 3 black-scaled on proximal 0.90, with 0-4 median spots or longitudinal streak of white or yellowish scales along dorsomesal margin; palpomere 4 with basal and apical bands of white scales, palpomere 5 entirely white-scaled; preapical black band 0.18-0.66 length of subapical white band (palpomeres 3 and 4) and 0.24-0.80 length of apical white band (palpomeres 4 and 5), subapical white band 0.77-1.46 length of apical white band. *Thorax* (Fig. 1A). Pleural and scutal integument light to dark brown, scutum largely covered with ashy gray tomentum; anterior promontory with long linear erect white scales, central area of scutum covered with narrow white spatulate scales (2.12-5.00 times as long as wide) which are longer than broad white spatulate scales (1.82-4.00 times as long as wide) on fossa, anterolateral margin (above anteprenotum) with patch of black spatulate scales before dorsocentral setae, with white spatulate scales immediately behind the black scales; scutellum with narrow white falcate or spatulate scales, sometimes with 2 or 3 white linear scales, with posterior row of light to dark brown setae (0-8 short and 5-10 long setae on middle; 1-3 short and 3-6 long setae laterally); anteprenotum sometimes with few pale or dark scales, with 9-19 long dark setae; postprenotum bare; pleura with some white scales on prealar area and upper and lower areas of mesokatepisternum, prespiracular area occasionally with a single falcate or spatulate scale; pleural setae: no proepisternal, 2-8 prespiracular, 2-6 prealar, 2-5 upper and 2-7 lower mesokatepisternal, 4-8 upper mesepimeral, and no lower mesepimeral. *Wing* (Fig. 1E). Pattern variable, pale markings usually dirty white to yellow, dark markings light to dark brown, common pattern follows: prehumeral and humeral pale spots on costa, corresponding part of vein R with gray scales; presector and sector pale spots on costa, subcosta and vein R;

subcostal pale spot on costa, subcosta and vein  $R_1$ ; preapical and apical pale spots on costa and vein  $R_1$ ; median dark spot on costa and subcosta without pale interruptions; dark spot distal to accessory sector pale spot on  $R_1$  with 1 or 2 pale interruptions, sector pale spot on R sometimes continuous with accessory sector pale spot on  $R_1$  (forming one large pale spot); preapical dark spot on costa and  $R_1$  0.55-2.00 (mode 0.96) length of preapical pale spot; remigium pale-scaled; humeral crossvein bare; presector dark spot on vein R 0.63-1.31 (mode 0.68) length of corresponding spot on costa,  $R_5$  dark-scaled with pale spot at base, sometimes with pale spot at middle and apex;  $R_2$  short, 1.20-2.00 length of vein  $R_{2+3}$ ;  $R_{2+3}$  long, with basal dark spot, rarely with distal dark spot; furcation of  $R_{2+3}$  originating at or beyond proximal 0.33 of preapical dark spot on  $R_1$ ;  $R_2$  and  $R_3$  usually with pale scales at base, middle and apex;  $R_{4+5}$  pale-scaled with 2 dark spots in subbasal and preapical positions, basal spur dark-scaled; M pale-scaled proximally, dark-scaled distally, with or without small dark spot between base of  $M_{3+4}$  and radiomedial crossvein;  $M_{1+2}$  and mcu largely dark-scaled, with pale scales at base and apex;  $M_1$ ,  $M_2$  and  $M_{3+4}$  with pale scales at middle, apex and usually at base, median pale spot on  $M_{3+4}$  1.00-5.00 length of dark spot on either side; CuA pale-scaled except for small subbasal and preapical dark spots; 1A with 3 dark spots in subbasal, median and preapical positions, median dark spot 0.18-0.90 length of pale spot on either side; wing apex usually with 2 broad pale spots, uppermost beginning before or at  $R_1$  and extending beyond  $R_2$  (occasionally divided by small dark fringe spot between  $R_1$  and  $R_2$ ), lowermost beginning at  $R_3$  and extending to  $R_{4+5}$ ; additional pale fringe spots include those at apices of  $M_1$ ,  $M_2$ ,  $M_{3+4}$ , CuA, and 1A. *Halter*. Scabellum pale, capitellum with pale scales dorsally and on anterior margin, dark scales ventrally and at apex. *Legs* (Fig. 1A,F). Anterior surface of forecoxa with small basal and apical scale-patches, basal patch usually comprised of dark scales with few pale scales on proximal side, sometimes comprised entirely of pale or dark scales, apical patch usually comprised of pale scales but sometimes comprised of dark scales; lateral surface of midcoxa with proximal and distal patches of pale scales; apicolateral margin of hindcoxa with line of pale scales. Trochanters largely dark-scaled, posterior surfaces of fore- and midtrochanters with pale scales distally. Femora and tibiae with scattered pale spots and narrow pale patch and/or fringe at apex, ventral surface of forefemur with indefinite stripe of pale scales on apical 0.20-0.33, mid- and hindfemora with indefinite stripe of pale scales on basal 0.50-0.70 of ventral surface; tarsi with pale bands and spots, banding of fore- and hindtarsi compared in Table 1, details follow: tarsomere 1 of all legs with dorsal patch or band of pale scales at apex; foretarsomere 1 with 5-8 posterodorsal pale spots, foretarsomeres 2 and 3 with basal and apical pale bands or dorsal patches, 0-2 pale spots on median dark band of foretarsomere 2, foretarsomere 4 with or without basal and apical pale patches or bands, foretarsomere 5 completely dark-scaled; midtarsomere 1 with 4-7 posterodorsal pale spots, midtarsomeres 1-3 with narrow pale spot dorsally at apex, midtarsomere 2 with or without median pale spot on posterodorsal surface, midtarsomere 3 occasionally with basal pale patch, midtarsomeres 4 and 5 completely dark-scaled; hindtarsomere 1 with 5-9 posterodorsal pale spots, hindtarsomere 3 with apical pale band and 0-2 median posterodorsal pale spots, hindtarsomeres 3 and 4 with basal and apical pale bands, hindtarsomere 5 completely pale-scaled. *Abdomen* (Fig. 1B). Integument light to dark brown, covered with numerous light to dark brown setae; terga I-IV

usually without scales, tergum II sometimes with few pale linear and/or falcate scales in middle posteriorly, these occasionally mixed with few narrow pale spatulate scales (4.00-7.00 times as long as wide), tergum IV sometimes with few pale falcate and/or narrow spatulate scales on posterior 0.33 or less, occasionally with few pale scales laterally as well, terga V and VI without scales or with sparse pale falcate and/or spatulate scales over posterior 0.5 and lateral margins; terga VII and VIII largely or posteriorly covered with rather broad pale yellow falcate and/or spatulate scales (2.60-5.00 times as long as wide), with or without patches of dark brown to black spatulate scales on posterolateral corners. Sterna II-V rarely with scales; sterna VI and VII with few scattered pale spatulate scales and median patch of black spatulate scales posteriorly, sternum VIII largely covered with pale spatulate and/or falcate scales laterally.

**MALE.** Like female except as follows. *Head.* Setae of antennal whorls longer, more numerous; proboscis length 1.67-2.13 mm, ratio to length of forefemur 1.34-1.51; length of maxillary palpus 1.70-2.05 mm, ratio to proboscis length 0.95-1.13, with 2 distal palpomeres swollen, integument pale between palpomeres 2 and 3, palpomere 3 with whitish scales along dorsomesal surface (sometimes also on palpomere 2), apex of palpomere 3 with dorsal patch of white scales and 8-10 moderately long setae, dorsal surface of palpomeres 4 and 5 white-scaled except for black scales at base, palpomere 4 with moderately long setae along mesal margin of pale scaling, ventrolateral line of dark scales and row of moderately long setae from near base of palpomere 4 to near apex of palpomere 5. *Wing.* As in female except as follows: preapical dark spot on costa 0.40-1.66 length of preapical pale spot; presector dark spot of vein R 0.88-1.00 length of corresponding spot on costa; dark fringe spot between apices of  $R_1$  and  $R_2$  usually absent. *Legs.* Fore- and midtarsomeres 1-3 with narrow dorsal pale band or patch at apex, occasionally with small basal pale patch on foretarsomeres 2 or 3. *Abdomen.* Tergum II and III without scales or with few linear or falcate scales posteriorly in middle; terga IV-VI with or without scattered pale falcate and/or spatulate scales, mainly posterior when present; tergum VII mainly with pale spatulate scales, with or without patches of black spatulate scales on posterolateral corners; tergum VIII (ventral in position) usually with scattered pale scales anteriorly, with black scales posteriorly. Sternum VII with sparse pale scaling posteriorly; sternum VIII (dorsal in position) pale-scaled.

**Egg** (Fig. 7). See Table 2 for comparison with other species. Length 0.40-0.50 mm, width 0.15-0.18 mm; deck usually complete but sometimes divided into anterior, median and posterior parts; frill incomplete in middle on both sides, occurring in anterior and posterior parts, distance between anterior and posterior frills 0.29-0.50 total length of deck; ratio of width to length of part of deck enclosed by anterior frill 0.29-0.50, ratio of width between floats to length of part of deck between anterior and posterior frills 0.28-0.46, ratio of width to length of part of deck enclosed by posterior frill 0.25-0.45; float with 13-21 ridges, confluent with median part of deck (part without frill).

**Material examined.** Some 250 progeny broods (986 females; 713 males), approximately 1,000 wild-caught females, and 50 egg batches. Additionally, hundreds of adult specimens were examined in the BM, IM, NICD, and NMNH.

**Distribution.** *Anopheles maculatus* is known from numerous localities in Bangladesh, Burma, China, India, Indonesia, Kampuchea, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka, Taiwan, Thailand, and Vietnam. No specimens were available from Laos, but the species undoubtedly occurs there.

**Taxonomy.** Theobald (1901) described *maculatus* "from several ♀'s and two ♂'s in Dr. Rees' collection." Following his usual practice, Theobald apparently labelled both a male and a female as types. The type male was noted by Reid (1968). This specimen was borrowed from the BM and critically examined during this study. According to Christophers (1933), the type female is a specimen of *Anopheles karwari* (James), and is probably in the BM under that species. The whereabouts of other material from Rees' collection is unknown. To insure nomenclatural stability, the male labelled as type in the BM is hereby designated the lectotype of *Anopheles maculatus* Theobald. The lectotype is identified by a small museum "Type" label and two labels inscribed with "Anopheles/maculata./(Type). Theobald//Anopheles/costalis ♀/Hong Kong/22. 10.00." The first was written by Theobald. The second was probably written by Rees.

Knight and Stone (1977) list the depository for the type specimens of *hanabusai* as the Medical Zoology Laboratory, Institute for Infectious Diseases, University of Tokyo. The collection formerly housed in this facility now resides in the Department of Parasitology, Institute of Medical Science, University of Tokyo. The collection contains four specimens, two males and two females, identifiable as syntypes of *hanabusai*. Yamada (1925) based his description of this species on "four females and two males from Kagi, Formosa." He indicated that some of these specimens were collected by J. Hatori in May 1917 and some by S. Hirayama on 15 April 1921. The identity of these specimens is uncertain. The males resemble specimens of *maculatus* in most respects while the females share characteristics with both *willmori* and *sawadwongporni*. For the time being, *hanabusai* is retained as a synonym of *maculatus*. The question of synonymy will be settled by further study. Christophers (1931) observed that only a small proportion of *maculatus* females had pale speckling on palpomere 3 while the majority of females which he considered to be var. *willmori* usually had conspicuous speckling on this palpomere. During this study, a wide range of variability was observed in this character. For this reason, the degree of pale speckling on palpomere 3 is considered to be of no value in separating *maculatus* and *willmori*. Based on the examination of progeny broods, it appears that the number and shape of scales on the abdominal terga are completely diagnostic for *maculatus*.

*Anopheles maculatus* is a common species which is widely distributed in the Oriental Region. It has been collected in association with all of the other members of the group in Thailand.

*Anopheles (Cellia) pseudowillmori* (Theobald)

**pseudowillmori** Theobald, 1910 (*Nyssorhynchus*). Synonymy with *maculatus* Theobald by James and Liston, 1911. RESURRECTED FROM SYNONYMY.



*Nyssorhynchus pseudowillmori* (Theobald) of James and Liston, 1911 (synonymy with *maculatus*).

*Anopheles maculatus* Theobald of Christophers, 1931 (in part, pilose form); Christophers and Barraud, 1931 (E; in part); Reid et al, 1966 (A,L; in part).

*Anopheles (Myzomyia) maculatus* Theobald of Christophers, 1933 (♂,♀,P,L,E; in part).

*Anopheles (Cellia) maculatus* Theobald of Reid, 1968 (♂,♀,P,L,E; in part).

*Anopheles (Cellia) maculatus* I of Green et al, unpublished data.

**Adult.** This species is easily recognized by the absence of scales on abdominal terga II-VII, vein  $R_2$  more than 2.00 length of vein  $R_{2+3}$ , and furcation of  $R_{2+3}$  originating at proximal end of preapical dark spot on vein  $R_1$ . *Anopheles pseudowillmori* is like *maculatus* except for the following.

**FEMALE.** *Head* (Fig. 2A,B). Proboscis length 1.60-2.28 mm, ratio to length of forefemur 1.12-1.22; length of maxillary palpus 1.56-1.90 mm, ratio to proboscis length 0.89-1.02, palpomere 3 occasionally with dorsomesal spot or streak of whitish scales, preapical black band 0.28-0.56 length of subapical white band and 0.25-0.52 length of apical white band, subapical white band 0.90-1.17 length of apical white band. *Thorax*. Central area of scutum with narrow white spatulate scales (3.22-5.00 times as long as wide), scales shorter and broader on fossa (2.50-3.50 times as long as wide); scutellum with 2-8 short and 5-9 long setae on middle and 2-6 short and 2-6 long setae laterally; anteprenotum usually without scales, occasionally with few scales dorsally, with 10-14 dark setae; pleural setae: 2-5 prespiracular, 2-4 prealar, 3-5 upper and 1-5 lower mesokatepisternal and 4-8 upper mesepimeral. *Wing* (Fig. 2D). Median dark spot on costa and subcosta without pale interruptions; median dark spot on subcosta and  $R_1$  sometimes with pale interruption near base, this interruption sometimes continuous with sector pale spot; preapical dark spot on costa 1.07-4.50 (mode 1.85) length of preapical pale spot;  $R_2$  long, 1.85-2.50 length of  $R_{2+3}$ ; furcation of  $R_{2+3}$  originating at or within proximal 0.33 of preapical dark spot on  $R_1$ . *Legs* (Fig. 2E). Essentially as in *maculatus*; banding of fore- and hindtarsi compared in Table 1. *Abdomen* (Fig. 2C). Integument light to dark brown with numerous light to dark brown setae; terga I-VII without scales; tergum VII infrequently with few pale linear and/or falcate scales laterally; tergum VIII with pale linear and narrow spatulate scales, often with some black scales on posterolateral corners. Sterna I-VII without scales; sternum VIII with pale linear and/or narrow spatulate scales laterally.

**MALE.** *Head*. Proboscis length 2.12-2.43 mm, ratio to length of forefemur 1.45-1.54; length of maxillary palpus 1.70-2.43 mm, ratio to proboscis length 0.94-1.02. *Wing*. Preapical dark spot on costa 0.93-2.00 length of preapical pale spot;  $R_2$  shorter, 1.44-2.00 length of  $R_{2+3}$ ; furcation of  $R_{2+3}$  originating at or within proximal 0.50 of preapical dark spot on  $R_1$ . *Legs*. Foretarsomeres 1-3 with apical pale patches, foretarsomeres 2 and 3 occasionally with basal pale patch. *Abdomen*. Terga and sterna I-VII without scales, tergum VIII (ventral in position) with some narrow pale and black spatulate scales, sternum VIII (dorsal in position) with few narrow pale spatulate scales posteriorly.

**Egg** (Fig. 7). Resembles *maculatus* except as follows: ratio of median width of deck between floats to length of part of deck between anterior and posterior frills 0.60-3.50; distance between anterior and posterior frills 0.08-0.30 total length of deck, frill occasionally complete (or nearly so) on 1 side; float with 15-23 ridges. See Table 2 for comparison with other species.

**Material Examined.** 21 progeny broods (162 females; 130 males, chorions of 11 egg batches), 119 wild-caught females, 34 females and 13 males reared from wild-caught larvae and/or pupae. An unknown number of adult specimens were also examined in the BM, IM, NICD, NMNH.

**Distribution.** *China.* Yunnan (Mengla Xian). *India:* Assam (Ledo, Shillong), Punjab (Jalpaiguri), Kasauli. *Nepal:* Bhimpliedi, Hetaura, Naraghat, Griuyanga. *Thailand:* Chiang Mai, Mae Hong Son (Mae Sariang). *Vietnam:* Tonkin.

**Taxonomy.** The original description of *pseudowillmori* is of the female only (Theobald, 1910) and the type series in the Indian Museum, Calcutta, consists of three females numbered 9382/16, 3959/15, and 3960/15, each bearing a label with "Meenglas, Dooars, Jalpaiguri, 13.vii.1907, C. Wallich." Specimen number 9382/16 is also labelled "Type ♀." We consider this specimen to be the holotype and the other specimens to be paratypes of *pseudowillmori*. The holotype is missing one wing, one foreleg, one hindleg (the other hindleg is missing tarsomeres 4 and 5), and the abdomen is covered by an unknown substance, but the specimen is still identifiable as *pseudowillmori* by the point of furcation of vein  $R_{2+3}$  and the length of vein  $R_2$ . The holotype is unusual in that the intact wing has only one spot (basal) on vein  $R_{4+5}$  (Fig. 2D).

*Anopheles (Cellia) willmori* (James)

**willmori** James, in Theobald, 1903 (*Nyssorhynchus*). Change to subspecific rank by Christophers, 1931. RESTORED TO SPECIFIC RANK.

**maculosa** James and Liston, 1903 (*Neocellia willmori* var.). Synonymy by Christophers, 1931.

**indica** Theobald, 1907 (*Neocellia*). Synonymy by Christophers, 1931.

**dudgeonii** Theobald, 1907 (*Neocellia*). Synonymy by Christophers, 1931.

*Neocellia willmori* James of James and Liston, 1911 (♀).

*Anopheles maculatus* var. *willmori* James of Christophers, 1931 (in part); Christophers and Barraud, 1931 (E; in part); Reid et al, 1966 (A,L; in part).

*Anopheles (Myzomyia) maculatus* var. *willmori* James of Christophers, 1933 (A,P,L,E; in part).

*Anopheles (Cellia) maculatus* var. *willmori* of Reid, 1968 (♂,♀,P,L,E; in part).

*Anopheles (Cellia) maculatus* H of Green et al, unpublished data.

**Adult.** This species is distinctly larger than the other members of the group and is easily recognized by the presence of numerous pale spatulate scales on abdominal terga II-VIII. It differs from *sawadwongporni* in having 0-5 pale spots on palpomere 3, 0-3 median pale spots on foretarsomere 2, and vein  $R_{2+3}$  with dark spot at base only. Foretarsomere 3 has basal and apical pale patches in the male. This species is like *maculatus* except for the following.

**FEMALE.** *Head* (Fig. 3A,B). Proboscis length 1.51-2.32 mm, ratio to length of forefemur 1.16-1.34; length of maxillary palpus 1.55-2.36 mm, ratio to proboscis length 0.82-1.01, palpomere 3 with 0-5 dorsomesal white spots; preapical black band 0.18-0.56 length of subapical white band and 0.17-0.53 length of apical white band, subapical white band 0.94-1.13 length of apical white band. *Thorax*. Central area of scutum covered with white spatulate scales (2.65-5.00 times as long as wide), those on fossa shorter and broader (1.90-3.00 times as long as wide); scutellum with 2-10 short and 4-9 long setae medially, with 2-7 short and 2-7 long setae laterally; anteprenotum with 0-2 pale scales and 9-20 dark setae; pleural setae: 3-7 prespiracular, 2-6 prealar, 3-5 upper and 2-5 lower mesokatepisternal, and 5-12 upper mesepimeral. *Wing* (Fig. 3D). Preapical dark spot on costa 0.88-4.42 (mode 1.55) length of preapical pale spot;  $R_{2+3}$  with basal dark spot;  $R_2$  short, 1.13-1.95 length of  $R_{2+3}$ ; M usually without dark spot between base of  $M_{3+4}$  and radiomedial crossvein. *Legs* (Fig. 3E). Anterior surface of forecoxa with basal patch of pale scales or combination of pale and dark scales; banding of fore- and hindtarsi compared in Table 1, foretarsomere 2 usually with 0-3 pale spots on median dark band, mid- and hindtarsomeres 2 usually with 0-3 median pale spots, midtarsomere 3 and sometimes 2 and 4 usually with basal pale patch. *Abdomen* (Fig. 3C). Tergum I occasionally with 1-3 pale spatulate scales; terga II-VIII densely or largely covered with pale spatulate scales (2.70-4.17 times as long as wide), occasionally with few pale linear and/or falcate scales; terga IV-VIII usually with patches of light brown to black spatulate scales on posterolateral corners. Sterna IV-VIII usually with scattered pale spatulate scales laterally; sternum VII (and occasionally VI) with median patch of black spatulate scales posteriorly; sternum VIII with patches of pale spatulate scales laterally.

**MALE.** Like female except as follows. *Head*. Proboscis length 1.75-1.93 mm, ratio to length of forefemur 1.37-1.46; length of maxillary palpus 1.75-1.93 mm, ratio to proboscis length 0.98-1.01. *Legs*. Foretarsomere 3, and occasionally 2 and 4, with basal pale patches. *Abdomen*. Tergum VII usually with patch of brown to black spatulate scales posteriorly; tergum VIII (ventral in position) largely or posteriorly covered with black spatulate scales, usually also with some pale scales. Sterna V-VII with some scattered pale scales; sternum VII (and sometimes VI) also with median patch of black scales on posterior margin; sternum VIII (dorsal in position) pale-scaled.

**Egg** (Fig. 7). Generally similar to *maculatus* ratio of width between floats to length of part of deck between anterior and posterior frills 0.50-0.80; distance between anterior and posterior frills 0.26-0.50 total length of deck; sometimes with 1 or 2 small isolated areas of deck surrounded by frill at both anterior and posterior ends of egg. See Table 2 for comparison with other species.

**Material Examined.** 13 progeny broods (112 females; 94 males; chorions of 10 egg batches), 22 wild-caught females, 39 females and 41 males reared from wild-caught larvae and/or pupae. An unknown number of adult specimens was examined in the BM, IM, NICD, and NMNH.

**Distribution.** *India:* Punjab (Ferozepore), Almora Kumaon, Kasauli, Kalpa, Assam (Ledo). *Nepal:* Bhimphedi. *Pakistan:* Kashmir. *Thailand:* Chiang Mai.

**Taxonomy.** Stone (1967) emended the original spelling of the name of this species to *willmorei* to agree with Willmore, the surname of the individual after whom James (in Theobald, 1903) named the species. But the original spelling *willmori* appears three times in James' description, indicating that James considered the stem of Willmore to be willmor- when forming the genitive case (see Article 31a(ii), *International Code of Zoological Nomenclature*, 1985). Consequently, we consider *willmorei* as an unjustified emendation of the specific name established as *Nyssorhynchus willmori* James, 1903.

James described *willmori* from an undisclosed number of females collected in Kashmir (Pakistan). The BM collection contains a single female bearing a red-bordered type label with "Nyssorhynchus" written above and "willmorei/James" written below the word "Type." It is accompanied by a second label inscribed with "Kashmir/Lt. Willmore." It is apparent that the first label was written sometime after Stone (1967) changed the spelling of *willmori* to *willmorei*. The information on the second label indicates that the specimen was probably before James when he described *willmori*, but we cannot be certain that it was the only specimen. On the contrary, James' comments indicate that he had more than one specimen before him when he described this species. Without any evidence to suggest that this specimen is anything more than a syntype, we hereby recognize it as the lectotype of *Nyssorhynchus willmori* James.

Variety *maculosa* was also described from an undisclosed number of females (James and Liston, 1911). There is a single specimen in the BM bearing four labels with the following information: "? Type or paratype/S.P.C//Willmori/var/maculosa//This is labelled by James and is I think/one of the original specimens sent to him/by me from Kalka, Punjab//B.M./1924.277." The first and third labels, obviously written by S. R. Christophers, clearly indicate that James and Liston had more than one specimen before them when they described *maculosa*. Since Christophers was uncertain about the status of this specimen, we hereby designate it the lectotype of *Neocellia willmori* var. *maculosa* James and Liston. The lectotype agrees with *willmori* in all details except midtarsomere 3 is without a basal pale band. Some Thai specimens also lack a basal pale band on this tarsomere.

The type series of *indica* and *dudgeonii* each include a male and female labelled as types. These specimens differ from the lectotype of *willmori* in several essential characters. The names are retained as synonyms of *willmori* pending further study. The taxonomic status of these nominal forms will be resolved in the forthcoming revision of the group in the Oriental Region.

#### *Anopheles (Cellia) sawadwongporni* New Species

*Anopheles maculatus* var. *willmori* James of Reid et al, 1966 (in part, adults from "Chiangmai").

*Anopheles (Cellia) maculatus* A of Green, 1982; Green and Baimai, 1984; Baimai et al, 1984; Green et al, 1985.

**Adult.** This species is easily recognized by the combination of vein  $R_{2+3}$  with 2 dark spots, palpomere 3 usually without dorsomesal pale scaling, posterior 0.33-1.00 of abdominal terga II-VIII covered with pale spatulate scales, and patches of black spatulate scales on posterolateral corners of terga III-VIII. Like *maculatus* except for the following.

**FEMALE.** *Head* (Fig. 4C,D). Proboscis length 1.37-1.88 mm, ratio to length of forefemur 1.00-1.25; length of maxillary palpus 1.33-1.76 mm, ratio to proboscis length 0.78-1.02, palpomeres 2 and 3 black-scaled except at apex, infrequently with dorsomesal patch of pale scales, preapical black band 0.10-0.62 length of subapical white band and 0.10-0.73 length of apical white band, subapical white band 0.71-1.45 length of apical white band. *Thorax* (Fig. 4A). Integument dark brown; central area of scutum with narrow white spatulate scales (2.73-4.00 times as long as wide), scales on fossa shorter and broader (1.75-3.22 times as long as wide); scutellum with white linear or falcate and spatulate scales, posterior row of 4-7 long and 1-7 short setae on middle and 2-4 long and 0-3 short setae on each side; pleural setae: 1-5 prespiracular, 2-6 prealar; 2-4 upper and 3-5 lower mesokatepisternal, and 5-8 upper mesepimeral. *Wing* (Fig. 4E). Preapical dark spot on costa 0.87-2.33 (mode 1.60) length of preapical pale spot; presector dark spot on R 0.76-1.14 (mode 1.00) length of corresponding dark spot on costa;  $R_2$  short, 1.32-1.96 length of  $R_{2+3}$ ;  $R_{2+3}$  with 2 dark spots on at least one wing, distal spot near furcation rarely absent (sometimes distinct only on ventral surface of wing), the two spots occasionally join to form a single large spot;  $R_{4+5}$  with a median dark spot in one specimen examined; M occasionally with small dark spot between base of  $M_{3+4}$  and  $rm$ ;  $M_{3+4}$  with long median pale spot, 1.05-5.00 (mode 2.58) length of dark spot on either side; 1A with short to long median dark spot, usually less than 0.55 length of pale spot on either side, dark fringe spots usually present before apex of  $R_1$  and between apices of  $R_3$  and  $R_{4+5}$ . *Legs* (Fig. 4F). Anterior surface of forecoxa with patch of pale and dark scales at base, sometimes with pale scales only, rarely with dark scales only; femora, tibiae, and tarsi essentially as in *maculatus*, banding of fore- and hindtarsi compared in Table 1; median dark band on fore- and midtarsomere 2 usually without pale spots; midtarsomere 3 usually without basal pale patch; hindtarsomere 2 with 0-3 median posterodorsal pale spots. *Abdomen* (Fig. 4B). Integument dark brown, covered with dark setae; posterior 0.33-0.75 of terga II-IV sparsely or densely covered with pale spatulate scales (2.70-6.00 times as long as wide), occasionally with few pale falcate and black spatulate scales intermixed, posterolateral corners of terga III and IV usually with few black spatulate scales (occasionally on posterolateral corners of tergum II as well); terga V-VIII largely covered with pale spatulate scales (2.33-4.00 times as long as wide), also with conspicuous patches of black spatulate scales on posterolateral corners. Sterna IV-VII with few scattered pale spatulate scales and median patch of black spatulate scales on posterior margin; sternum VIII with pale falcate and/or spatulate scales laterally.

**MALE.** As for female except as follows. *Head*. Proboscis length 1.75-2.15 mm, ratio to length of forefemur 1.40-1.52; length of maxillary palpus 1.85-2.13 mm, ratio to proboscis length 0.94-1.06. *Legs*. Foretarsomeres 1-3 with apical pale patch or band only. *Abdomen*. Terga II-VI sometimes with median patch of

pale spatulate scales on posterior 0.33-0.75; tergum VIII (ventral in position) with variable amount of pale scaling, with median patch of black spatulate scales posteriorly; sternum VIII (dorsal in position) largely pale-scaled.

**Egg** (Fig. 7). Length 0.40-0.45 mm, width 0.14-0.16 mm; deck narrow, width 0.07-0.10 total length of egg, usually completely enclosed by frill, sometimes divided into anterior and posterior parts with separate frill enclosing each part; float with 14-21 ridges, separated from deck by frill and/or narrow strip of outer chorion. See Table 2 for comparison with other species.

**Type data.** The type series contains 33 females, 22 males, 51 larval exuviae, 51 pupal exuviae, 11 fourth-instar larvae, and chorions from 4 egg batches. Holotype female, TH(58)-16, and allotype male, TH(58)-11, with associated larval and pupal exuviae mounted on slides: THAILAND, Phrae Province, Amphoe Rong Kwang, Ban Thung Khua Mu 6, 420 m, 21 October 1985, Coll. P. Sawadwongporn. Paratypes (all with same data as holotype): TH(58) mother, TH(58) egg batch, TH(58)-1 through -10, -12, -13, -14 progeny (5 females and 8 males), TH(58) progeny (5 fourth-instar larvae); TH(54) mother, TH(54) egg batch, TH(54)-1 through -13 progeny (9 females and 4 males), TH(54) progeny (6 fourth-instar larvae); TH(60) mother, TH(60) egg batch, TH(60)-1, -2, -3 progeny (1 female and 2 males); TH(63) mother, TH(63) egg batch, TH(63)-2 through -20 progeny (12 females and 7 males). All progeny paratypes have associated larval and pupal exuviae. Holotype, allotype, and 19 paratypes (6 females, 8 males, and 5 fourth-instar larvae) deposited in the National Museum of Natural History, Smithsonian Institution, Washington, DC. Other paratypes divided equally between BM and Department of Medical Entomology, AFRIMS.

Also examined were: 151 progeny broods (521 females; 295 males), more than 500 wild-caught females, 162 females and 148 males with associated larval and/or pupal exuviae, and chorions from about 50 egg batches. Additional adult specimens were examined in the BM and NMNH.

**Distribution.** *Burma:* Kyauk-ta-ga (North of Rangoon). *China:* Ya Yian, Hainan Island. *Kampuchea:* Campot Po Phnum Twea, Snoul Kbal Trach, Campot Champaul, Paeko Chi Meang. *Thailand:* Chanthaburi, Chiang Mai, Kamphaeng Phet, Kanchanaburi, Khon Kaen, Lampang, Loei, Mae Hong Son, Nakhon Nayok, Nakhon Ratchasima, Phang Nga, Phet Buri, Phetchabun, Phrae, Phitsanulok, Prachin Buri, Pathum Thani, Sakon Nakhon, Saraburi, Tak, Udon Thani, Uttaradit. *Vietnam:* Balang Quang, Leng Vei RVN, Kon Tum, Plei Djeziug, Tonkin.

*Anopheles sawadwongporni* is widely distributed in Thailand, but does not appear to have a continuous distribution in the south. Only one specimen was collected south of Phet Buri Province (in Phang Nga Province). The species commonly occurs at low and high altitudes in association with all other members of the group.

**Taxonomy.** *Anopheles sawadwongporni* is the most common species of the *maculatus* group in the central and northern foothills and mountains of Thailand. It is smaller and darker than other members of the group. About 97% of the specimens of this species resemble *notanandai* in having a distal dark spot on

vein  $R_{2+3}$ . This spot is absent in the other species of the group. Specimens that do not have a distal spot on  $R_{2+3}$  can be separated from *dravidicus* by the presence of anterior pale and dark scales, or pale scales only, at the base of the forecoxa. In some specimens these scales are all dark, but in this case vein  $R_{2+3}$  always has a distal dark spot. *Anopheles sawadwongporni* can be separated from *willmori* by the absence of both a distinct pale spot on palpomere 3 and pale spots (normally) on the median dark band of foretarsomere 2. Another character that may help separate these species is the absence of basal pale patches on midtarsomeres 3 and 4 in *sawadwongporni*. These patches are normally present in *willmori*. These species can sometimes be separated by the presence of a dark spot between the base of  $M_{3+4}$  and the radiomedial crossvein in *sawadwongporni*. *Anopheles sawadwongporni* occasionally has a short medial pale mark on  $M_{3+4}$  and a long median dark mark on 1A which sometimes makes the separation of this species and *notanandai* difficult. These characters are less common in *sawadwongporni* (present only in 3 or 4% of the specimens examined). Previously this species probably has been misidentified as *willmori*. We have examined specimens from Burma, Kampuchea, Thailand and Vietnam previously considered to be *maculatus* and *willmori* which are obviously *sawadwongporni*. We have not seen specimens from India.

*Anopheles sawadwongporni* is dedicated with deepest respect and admiration to Mr. Phorn Sawadwongporn, Chief, Entomology Section, Malaria Division, Northern Region, Ministry of Health, Thailand, whose dedicated efforts contributed significantly to the recognition of this species. Virtually all native speakers of English would give the correct Thai pronunciation of the specific name if it was spelled as sawadwongpawni.

*Anopheles (Cellia) notanandai* New Species

*Anopheles (Cellia) maculatus* G of Green and Baimai, 1984; Baimai et al, 1984.

**Adult.** This species differs from the others, except some specimens of *sawadwongporni*, in having a shorter median pale spot on vein  $M_{3+4}$ . It is reliably distinguished from *sawadwongporni* in the egg stage (see). Adults of this species are like those of *sawadwongporni* except as follows.

**FEMALE.** *Head* (Fig. 5A,B). Proboscis length 1.20-1.80 mm, ratio to length of forefemur 1.04-1.25; length of maxillary palpus 1.33-1.63, ratio to proboscis length 0.91-1.00, palpomere 3 black-scaled except at apex, preapical black band 0.31-0.57 length of subapical white band and 0.26-0.67 length of apical white band, subapical white band 0.77-1.25 length of apical white band. *Wing* (Fig. 5D). Preapical dark spot on costa 1.42-3.80 (mode 1.50) length of preapical pale spot; vein  $R_{2+3}$  with 2 dark spots;  $R_2$  short, 1.20-1.75 length of  $R_{2+3}$ ,  $R_{4+5}$  occasionally with a median dark spot (observed in  $F_3$  progeny only);  $M_{3+4}$  usually with short median pale spot, 0.60-2.90 (mode 1.33) length of dark spot on either side, rarely longer than dark spots on both wings; 1A usually with long median dark mark, 0.45-1.20 (mode 0.80) length of pale mark on either side. *Legs* (Fig. 5E). As in *sawadwongporni*; banding of fore- and hindtarsi compared in Table 1. *Abdomen* (Fig. 5C). As in *sawadwongporni*.

**MALE.** *Head.* Proboscis length 2.00-2.13 mm, ratio to length of forefemur 1.44-1.59; length of maxillary palpus 2.00-2.05 mm, ratio to proboscis length 0.95-1.00.

**Egg** (Fig. 7). Adults of this species sometimes cannot be separated from *sawadwongporni* but the eggs are distinct. They are similar to those of *maculatus* except as follows: distance between anterior and posterior frills 0.12-0.30 total length of deck; floats with 13-17 ridges. See Table 2 for comparison with other species.

**Type data.** The type series contains 21 females, 7 males, 22 larval exuviae, 22 pupal exuviae, 3 fourth-instar larvae, and chorions from 7 egg batches. Holotype female (TL155-1) and allotype male (TL155-4) with associated larval and pupal exuviae on slides: THAILAND, Phetchaburi Province, Amphoe Tha Yang, Ban Tah Cha Lao (13 07 N 99 38 E), 160 m, 22-27 Aug 1983, Coll. C. A. Green. Paratypes with same data as holotype - adult progeny paratypes with associated larval and pupal exuviae unless noted otherwise: TL155 mother, TL155 egg batch, TL155-2,-3 progeny (2 females), TL155 progeny (2 larval and 2 pupal exuviae without associated adults); TL161 egg batch, TL161-1 through -5 progeny (5 females); TL141 egg batch, TL141-1, -2, -3 progeny (2 females and 1 male), TL141 progeny (fourth-instar larva); TL135 egg batch, TL135-3 progeny (female without associated larval and pupal exuviae); TL126 mother, TL126 egg batch, TL126-1,-2,-3,-4 progeny (2 females and 2 males), TL126 progeny (fourth-instar larva), TL126-5 progeny (larval and pupal exuviae without associated adult); TL101 mother, TL101 egg batch, TL101-1,-2,-4 progeny (2 females and 1 male), TL101 progeny (fourth-instar larva); TL96 egg batch, TL96-1 through -5 (3 females and 2 males). The following paratypes are divided between the BM and Department of Entomology, AFRIMS: 4 females and 4 males with associated larval and pupal exuviae and 1 fourth-instar larva. The holotype, allotype, and remaining paratypes are deposited in the National Museum of Natural History, Smithsonian Institution, Washington, DC.

Other specimens examined include 9 wild-caught females and 1 progeny brood comprised of 4 females, 15 males, 3 fourth-instar larvae, and the egg chorions.

**Distribution.** *Thailand* Kanchanaburi, Nakhon Phanom, Phetchaburi.

**Taxonomy.** It is not yet possible to separate adults of *notanandai* from those of *sawadwongporni* with certainty, primarily because of insufficient material for study. The recognition of *notanandai* as a distinct species is based on the morphological examination of only six progeny broods and nine wild-caught females, and a study of polytene chromosomes. Besides these specimens, the eggs of a progeny brood obtained from another female were studied and found to be distinct from the eggs of *sawadwongporni*. Seventy percent of the adults from this series had a short median pale spot on vein M<sub>3+4</sub> and a long median dark spot on vein 1A as indicated in the description above. Thirty percent of these specimens could not be distinguished from *sawadwongporni*.



This species is named in honor of Dr. Vimol Notananda who devoted much of his life to the study of malaria and other tropical diseases in Thailand. He served as the Director of the Malaria Division and Director General of the Department of Health, Ministry of Public Health, before he retired in 1980. The conventional English pronunciation of the Latinized name is notanoni.

*Anopheles (Cellia) dravidicus* Christophers

**dravidicus** Christophers, 1924 (*Anopheles maculatus* var.). Synonymy with *maculatus* Theobald by Christophers, 1931. RESURRECTED FROM SYNONYMY.

*Anopheles maculatus* Theobald of Christophers, 1931 (nominotypical form, in part); Christophers and Barraud, 1931 (E; in part); Reid et al, 1966 (A,L; in part).

*Anopheles (Myzomyia) maculatus* Theobald of Christophers, 1933 (♂, ♀, P, L, E; in part).

*Anopheles (Myzomyia) maculatus* var. *dravidicus* Christophers of Bonne-Wepster and Swellengrebel, 1953 (A, L).

*Anopheles (Cellia) maculatus* Theobald of Reid, 1968 (♂, ♀, P, L, E; in part).

*Anopheles (Cellia) maculatus* C of Green, 1982; Green and Baimai, 1984; Baimai et al, 1984; Green et al, 1985.

**Adult.** This species closely resembles *sawadwongporni* and *maculatus* but differs in having no pale scales anteriorly at the base of the forecoxa and in having an additional dark spot in the middle of vein R<sub>4+5</sub>. The species is like *maculatus* except for the following.

**FEMALE.** *Head* (Fig. 6C,D). Proboscis 1.57-2.00 mm, ratio to length of forefemur 1.07-1.28; length of maxillary palpus 1.43-1.83 mm, ratio to proboscis length 0.85-1.05, palpomere 2 black-scaled except at apex, palpomere 3 mainly black-scaled, pale-scaled at apex and occasionally with 1-3 pale spots on dorsomesal aspect, preapical black band 0.31-0.65 length of subapical white band and 0.33-0.86 length of apical white band, subapical white band 0.71-1.53 length of apical white band. *Thorax* (Fig. 6A). Integument light to dark brown; pleural setae: 1-9 prespiracular, 2-7 prealar, 2-4 upper and 2-5 lower mesokatepisternal, and 6-8 upper mesepimeral; scutellum with 5-8 long and 2-10 short setae in middle, 2-5 long and 0-3 short setae on each side. *Wing* (Fig. 6E). Preapical dark spot on costa 0.84-1.28 (mode 1.00) length of preapical pale spot; vein R<sub>2+3</sub> only with basal dark spot; R<sub>2</sub> short, 1.12-1.90 length of vein R<sub>2+3</sub>; R<sub>4+5</sub> commonly with 3 dark spots in subbasal, median and preapical positions, median dark spot short or long, sometimes confluent with subbasal dark spot, occasionally absent, basal spur dark-scaled as usual. *Legs* (Fig. 6F). Base of forecoxa with or without anterior patch of black scales, rarely with pale scales; femora, tibiae, and tarsi essentially as in *maculatus*, banding of fore- and hindtarsi compared in Table 1; median dark band on fore- and midtarsomere 2 with or without pale spots; hindtarsomere 2 with 0-2 median posterodorsal pale spots. *Abdomen* (Fig. 6B). Integument light to dark brown, terga II-IV largely or partially covered with pale spatulate scales, sometimes with only few falcate or narrow spatulate scales posteromedially, posterolateral corners occasionally black-scaled; terga V-VIII

largely pale-scaled, posterolateral corners black-scaled, black scales frequently on terga VII and VIII only. Sterna V-VII usually with some scattered pale scales and median posterior patch of black scales, sternum VIII pale-scaled laterally.

**MALE.** As in female except as follows. *Head.* Proboscis length 2.15-2.35 mm, ratio to length of forefemur 1.34-1.43; length of maxillary palpus 1.38-2.50 mm, ratio to proboscis length 0.99-1.11. *Legs.* Foretarsomeres 2-4 usually with apical pale patches, infrequently with basal pale patches. *Abdomen* Tergum VIII (ventral in position) largely pale-scaled, with median patch of black scales. Sterna VI and VII covered posteriorly with black spatulate scales; sternum VIII (dorsal in position) pale-scaled.

**Egg** (Fig. 7). As described for *maculatus*. See Table 2 for comparison with other species.

**Material Examined.** 19 progeny broods (142 females; 91 males), 29 wild-caught females, 56 females and 41 males with associated larval and/or pupal exuviae, and chorions of 18 egg batches.

**Distribution.** *Burma:* (Kale Valley). *India:* Nilgiri Hills. *Thailand:* Chaing Mai, Kanchanaburi, Loei, Mae Hong Son, Phrae, Udon Thani.

**Taxonomy.** Christophers (1924) did not disclose the number of specimens in the type series of *dravidicus* but there are two specimens, a male and a female, labelled as types in the BM. The female is a fairly typical specimen of *dravidicus* with a pale spot on the median dark band of palpomere 3, an anterior patch of dark scales on the forecoxa, a few pale falcate and narrow spatulate scales on abdominal terga II and III, scattered pale spatulate scales on tergum IV, and three dark spots on vein R<sub>4+5</sub> of one wing. The male resembles some specimens of *maculatus* in having two dark spots on vein R<sub>4+5</sub> of both wings but the pale scaling of tergum IV is typical of *dravidicus*. To establish a standard for the application of the name of this species, the female is hereby designated the lectotype of *Anopheles maculatus* var. *dravidicus* Christophers. The lectotype has the following data: "A. maculatus/var. dravidicus/Type ♀ 9.5.24/S.R.C.// Nilgiri Hills/Khazan Chand/Oct. 1915//B.M./1924.277."

Only 1% of the specimens of *dravidicus* examined, those with a few falcate and/or narrow spatulate scales posteromedially on abdominal tergum II, could be confused with *maculatus*. These specimens were frequently almost identical to *maculatus* in having a basal patch of dark scales on the anterior surface of the forecoxa and patches of dark scales on the posterolateral corners of terga VII and/or VIII. An occasional specimen has only 2 dark spots on vein R<sub>4+5</sub>.

#### Preliminary key to adult females in Thailand

The following key is regarded as preliminary because it has not been tested on material collected throughout Thailand. We have carefully checked it against the available chromosomally identified females with a 98% agreement between the two means of identification.

1. Vein  $R_{2+3}$  with 2 dark spots on at least one wing, infrequently joined to form single large spot; abdominal terga II-IV largely or posteriorly covered with narrow to broad pale spatulate scales (Figs. 4B,E;5C) . . . . . 2
- Vein  $R_{2+3}$  with 1 dark spot on both wings; abdominal terga II-IV largely or posteriorly covered with pale falcate or pale spatulate scales, or without scales (Figs. 1B,E;2C;3C;6B) . . . . . 3
- 2(1). Vein  $M_{3+4}$  with median pale spot usually more than twice length of dark spot on either side on both wings; vein 1A usually with median dark spot less than 0.55 length of pale spot on either side on both wings (Fig. 4E) . . . . . **sawadwongporni** (in part)
- Vein  $M_{3+4}$  with median pale spot usually less than twice length of dark spot on either side on both wings; vein 1A usually with median dark spot more than 0.55 length of pale spots on either side on one wing (Fig. 5D) . . . . . **notanandai** (in part)
- 3(1). Abdominal terga II and III largely or posteriorly covered with pale spatulate scales; dark scales usually on posterolateral corners of terga IV-VIII (except some specimens of *dravidicus* and *willmori*) . . . . . 4
- Abdominal terga II and III without scales or with some pale falcate and/or few narrow pale spatulate scales posteriorly in middle; dark scales usually only on posterolateral corners of terga VII and/or VIII (except some specimens of *dravidicus* . . . . . 7
- 4(3). Anterior surface of forecoxa with small patch of dark scales at base; vein  $R_{4+5}$  with 3 dark spots (subbasal, median, and preapical), median spot occasionally absent or very long and nearly touching subbasal spot (Fig. 6A,E) . . . . . **dravidicus** (in part)
- Anterior surface of forecoxa with patch of pale and dark scales at base, this patch sometimes comprised entirely of pale scales, rarely comprised entirely of dark scales; vein  $R_{4+5}$  with 2 dark spots (subbasal and preapical), median dark spot rarely present . . . . . 5
- 5(4). Palpomere 3 with 1-5 distinct median pale spots, occasionally without spots (Fig. 3A); foretarsomere 2 usually with 1-3 distinct median pale spots, midtarsomere 3, and sometimes 4, with basal pale patch (Fig. 3E); abdominal terga II-IV entirely covered with pale spatulate scales; patches of dark scales on posterolateral corners of terga VII and VIII, occasionally on terga IV-VI as well (Fig. 3C) . . . . . **willmori**

- Palpomere 3 and foretarsomere 2 usually without median pale spots; midtarsomeres 3 and 4 without basal pale patches; abdominal terga II-IV only covered posteriorly with pale spatulate scales, patches of dark scales usually present on posterolateral corners of terga III-VIII, and sometimes II (Figs. 4B; 5C) . . . . . 6
- 6(5). Vein  $M_{3+4}$  with median pale spot usually more than twice length of dark spot on either side on both wings; vein 1A with median dark spot less than 0.55 length of pale spot on either side on both wings (Fig. 4E) . . . . . **sawadwongporni** (in part)
- Vein  $M_{3+4}$  with median pale spot usually less than twice length of dark spot on either side on both wings; vein 1A usually with median dark spot more than 0.55 length of pale spot on either side usually on one wing (Fig. 5D) . . . . . **notanandai** (in part)
- 7(3). Abdominal terga V-VII without scales, tergum VII infrequently with 1-3 pale scales laterally (Fig. 2C); furcation of vein  $R_{2+3}$  at proximal end of preapical dark spot on vein  $R_1$ , occasionally forking within proximal 0.33; vein  $R_2$  long, usually longer than twice length of vein  $R_{2+3}$  (Fig. 2D) . . . . . **pseudowillmori**
- Abdominal terga V-VII with numerous pale scales, occasionally on tergum VII only; furcation of vein  $R_{2+3}$  at or beyond proximal 0.33 of preapical dark spot on vein  $R_1$ ; vein  $R_2$  short, usually less than twice length of vein  $R_{2+3}$  . . . . . 8
- 8(7). Vein  $R_{4+5}$  with 3 dark spots on at least one wing (Fig. 6E) . . . . . **dravidicus**
- Vein  $R_{4+5}$  with 2 dark spots on both wings . . . . . 9
- 9(8). Abdominal tergum IV without scales or with few pale falcate and/or pale spatulate scales posteriorly in middle, sometimes on posterior margin only; posterolateral corners of terga VII and/or VIII, and rarely VI, with patches of dark scales (Fig. 1B) . . . . . **maculatus**
- Abdominal tergum IV sparsely covered with pale falcate and/or pale spatulate scales on posterior 0.50-0.75 (not confined to middle); dark scales usually on posterolateral corners of terga IV-VII, sometimes on tergum III as well (Fig. 6B)\* . . . . . **dravidicus**

\*Some atypical specimens of *maculatus* key here to *dravidicus*. In this case the user should look for pale scales on the anterior surface of the forecoxa. If pale scales are present, then the specimen cannot be *dravidicus*.

### Discussion

Taxonomists often implicitly use genetic criteria in making decisions regarding species status (e.g., Harrison, 1980) without giving an explicit outline of their methods. An essentially genetic approach to the study of morphological variation was used in this study. As Green (1981) pointed out, "morphological variation is complex, very rarely understood genetically, and very probably involves varying combinations of genetic components and environmental influences." For example, it is quite clear that size in anophelines is under strong genetic control (compare species of the *Myzomyia* series of the subgenus *Cellia* with those of the subgenus *Anopheles*), nevertheless it is possible to manipulate environmental conditions such as food availability and temperature so that the genetic basis for size is totally masked by environmental influences. The rearing of progeny broods under laboratory conditions helps to standardize any environmental component in morphological variation. Thus one can be reasonably certain that interspecific differences observed in such material are primarily due to genetic variation. The question now arises: are there environmental conditions in nature that will mask the genetic component to variation observed in the laboratory? This vital question can be resolved only by testing diagnostic characters in wild-caught specimens. Such a test should be made against a means of identification which is unambiguous irrespective of any environmental influence. In the case of the *maculatus* group, diagnostic characters were tested against species-specific chromosomal rearrangements seen in ovarian polytene chromosomes, i.e., the identities of wild-caught females were determined by morphological means and confirmed by the cytological examination of their polytene chromosomes. Where such a direct test is not possible, then wild-caught females should be compared with their laboratory-reared progeny.

The primary purpose of this paper has been to introduce formal names for the members of the *maculatus* group occurring in Thailand. This study is part of a revision of the *maculatus* group in the Oriental Region. The final revision will include descriptions of the larval and pupal stages as well as the adult and egg stages of all the species. The taxonomic status of the nominal forms of *hanabusai*, *indicus*, and *dudgeonii* also will be dealt with in the revision.

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**Table 1.** Comparison of tarsal banding in members of the *Anopheles maculatus* group in Thailand.

Character	maculatus	pseudowillmori	willmori	sawadwongporni	dravidicus	notanandai
<u>Foretarsus:</u>						
apical band/Ta <sub>1</sub> *	0.05-0.09	0.06-0.11	0.06-0.09	0.07-0.12	0.06-0.08	0.07-0.11
basal band/Ta <sub>2</sub>	0.05-0.17	0.11-0.22	0.04-0.18	0.13-0.31	0.11-0.27	0.12-0.22
apical band/Ta <sub>2</sub>	0.13-0.33	0.18-0.33	0.16-0.33	0.20-0.30	0.14-0.26	0.18-0.26
basal band/Ta <sub>3</sub>	0.10-0.30	0.08-0.38	0.14-0.29	0.18-0.32	0.14-0.28	0.16-0.27
apical band/Ta <sub>3</sub>	0.12-0.40	0.08-0.31	0.07-0.27	0.15-0.30	0.14-0.30	0.16-0.25
basal band/Ta <sub>4</sub>	0.25-0.42	0.20-0.31	0.22-0.43	0.28-0.50	0.25-0.38	0.25-0.28
apical band/Ta <sub>4</sub>	0.00-0.25	0.00-0.22	0.00-0.16	-	-	-
pale Ta <sub>1-2</sub> /dark Ta <sub>2</sub> **	0.27-0.70	0.21-0.88	0.33-0.55	0.46-0.91	0.33-0.75	0.45-0.75
pale Ta <sub>2-3</sub> /dark Ta <sub>3</sub>	0.88-1.66	0.85-1.60	0.55-1.40	0.55-1.16	0.66-1.16	0.62-1.16
<u>Hindtarsus:</u>						
apical band/Ta <sub>1</sub>	0.03-0.06	0.02-0.06	0.03-0.06	0.02-0.04	0.02-0.05	0.03-0.05
apical band/Ta <sub>2</sub>	0.13-0.26	0.18-0.27	0.20-0.29	0.15-0.27	0.17-0.26	0.16-0.24
basal band/Ta <sub>3</sub>	0.13-0.29	0.17-0.29	0.19-0.33	0.23-0.33	0.20-0.29	0.25-0.30
apical band/Ta <sub>3</sub>	0.22-0.32	0.24-0.32	0.30-0.39	0.28-0.40	0.29-0.38	0.30-0.35
basal band/Ta <sub>4</sub>	0.23-0.44	0.31-0.47	0.25-0.50	0.33-0.50	0.35-0.44	0.38-0.50
apical band/Ta <sub>4</sub>	0.22-0.38	0.21-0.35	0.27-0.41	0.25-0.41	0.29-0.44	0.25-0.31
pale Ta <sub>2-3</sub> /dark Ta <sub>3</sub>	0.58-1.40	0.73-1.57	0.81-2.42	1.11-2.33	1.00-1.55	1.20-1.50
pale Ta <sub>3-4</sub> /dark Ta <sub>4</sub>	1.88-3.50	1.83-4.00	2.33-5.66	2.33-5.33	2.80-4.66	2.30-4.66
pale Ta <sub>2-3</sub> /pale Ta <sub>3-4</sub>	0.84-1.00	0.75-1.00	0.81-1.14	0.71-0.94	0.80-1.00	0.92-1.00
pale Ta <sub>3-4</sub> /pale Ta <sub>4-5</sub>	0.92-1.25	0.86-1.23	1.00-1.32	0.90-1.36	1.07-1.23	1.03-1.46
dark Ta <sub>3</sub> /dark Ta <sub>4</sub>	1.56-3.00	1.83-3.75	2.00-3.33	1.20-3.00	1.25-3.00	1.20-2.25

\* Ratio of length of basal or apical pale band to length of tarsomere. Ta<sub>1</sub> = tarsomere 1, Ta<sub>2</sub> = tarsomere 2, etc.

\*\*Ratio of length of pale band across joint of tarsomeres 1 and 2 (or 2 and 3, etc.) to length of median dark band on tarsomere 2 (or 3, etc.).

**Table 2.** Comparison of egg measurements in members of the *Anopheles maculatus* group in Thailand.

Character	maculatus	pseudowillmori	willmori	sawadwongporni	dravidicus	notanandai
<u>General:</u>						
egg length (mm)	0.40-0.50	0.43-0.50	0.43-0.50	0.40-0.50	0.40-0.45	0.40-0.48
egg width (mm)	0.15-0.18	0.16-0.18	0.16-0.18	0.14-0.16	0.15-0.18	0.14-0.15
float ridge number	13-21	15-23	14-20	14-21	15-21	13-17
frill-frill/deck*	0.29-0.50	0.08-0.30	0.26-0.50	-	0.27-0.43	0.12-0.30
<u>Anterior deck**:</u>						
width/length	0.29-0.50	0.13-0.36	0.32-0.70	-	0.25-0.50	0.20-0.38
length/width	2.00-3.43	2.80-4.75	1.44-3.11	-	2.00-4.00	2.67-5.00
<u>Median deck ***:</u>						
width/length	0.28-0.46	0.60-3.50	0.50-0.80	-	0.20-0.50	0.36-0.60
length/width	1.43-3.57	0.28-1.90	1.33-2.83	-	2.00-5.00	0.80-2.75
<u>Posterior deck **::</u>						
width/length	0.25-0.45	0.17-0.32	0.35-0.65	-	0.25-0.86	0.20-0.38
length/width	2.25-4.00	3.14-6.00	1.57-2.80	-	1.75-4.00	2.75-4.67

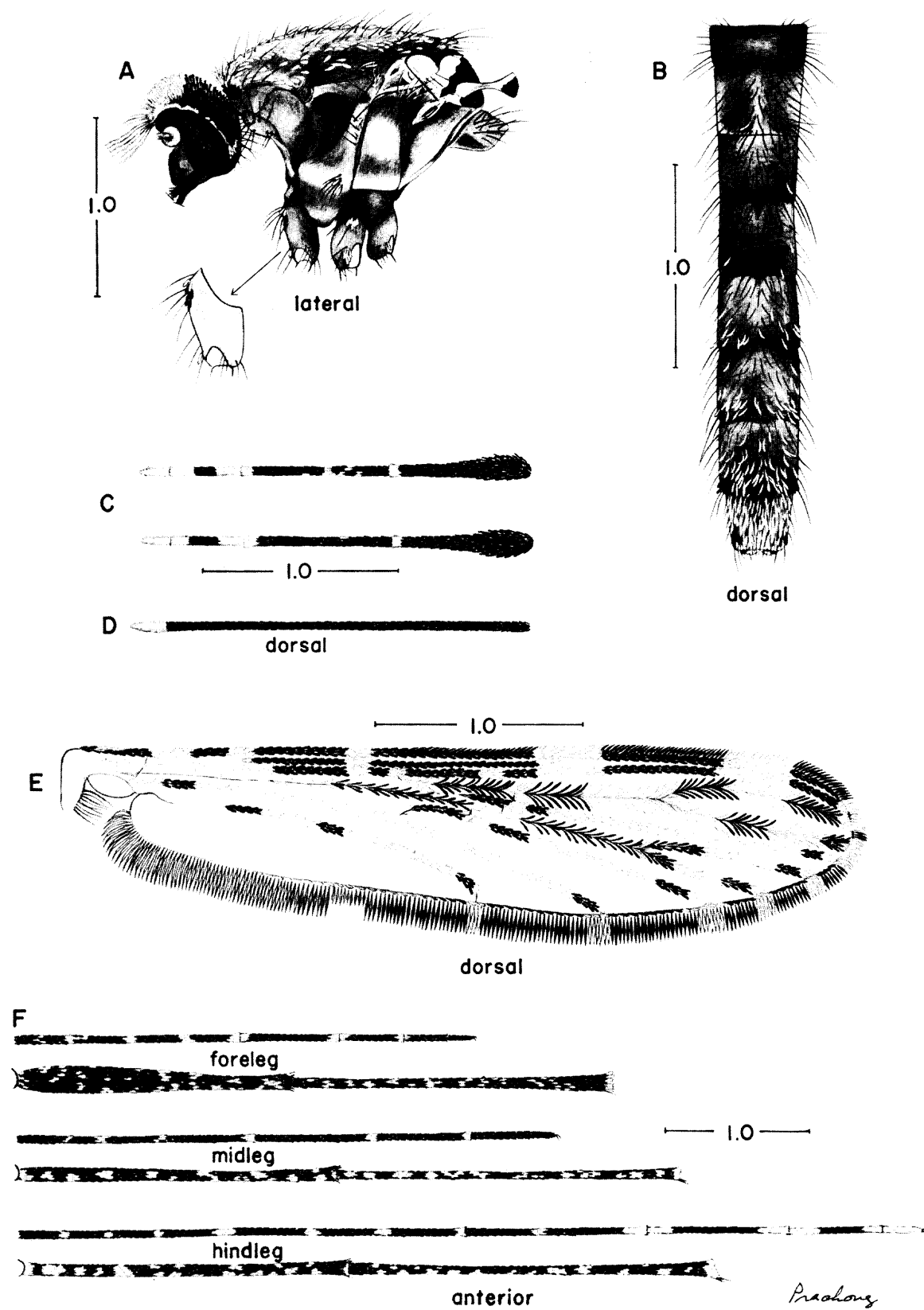
\* Ratio of length of deck between anterior and posterior frills to total length of deck.

\*\* Ratio of length or width of deck enclosed by frill.

\*\*\* Ratio of length or width of deck between anterior and posterior frills to distance between floats.

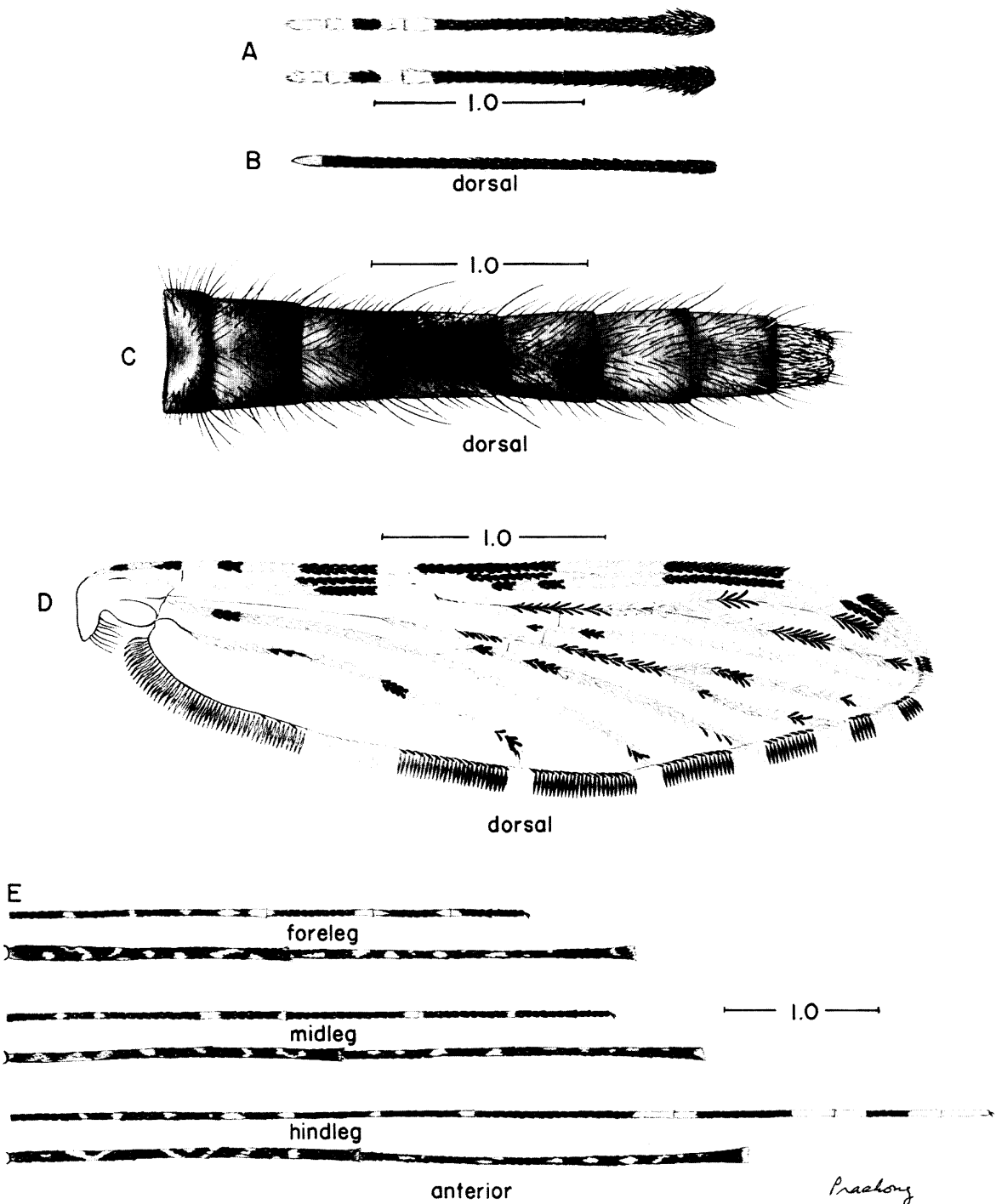
maculatus

Fig. 1



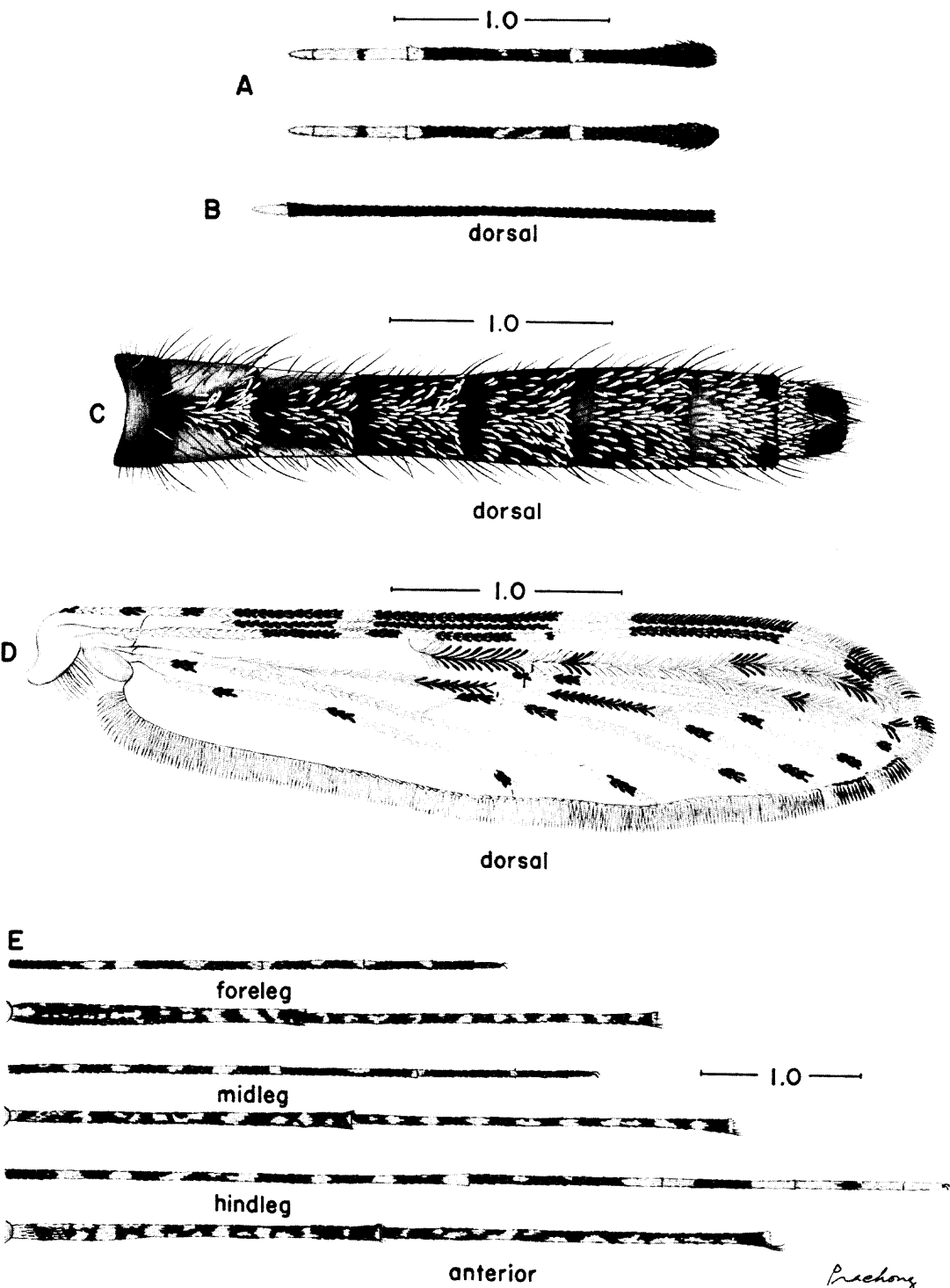
pseudowillmori

Fig. 2



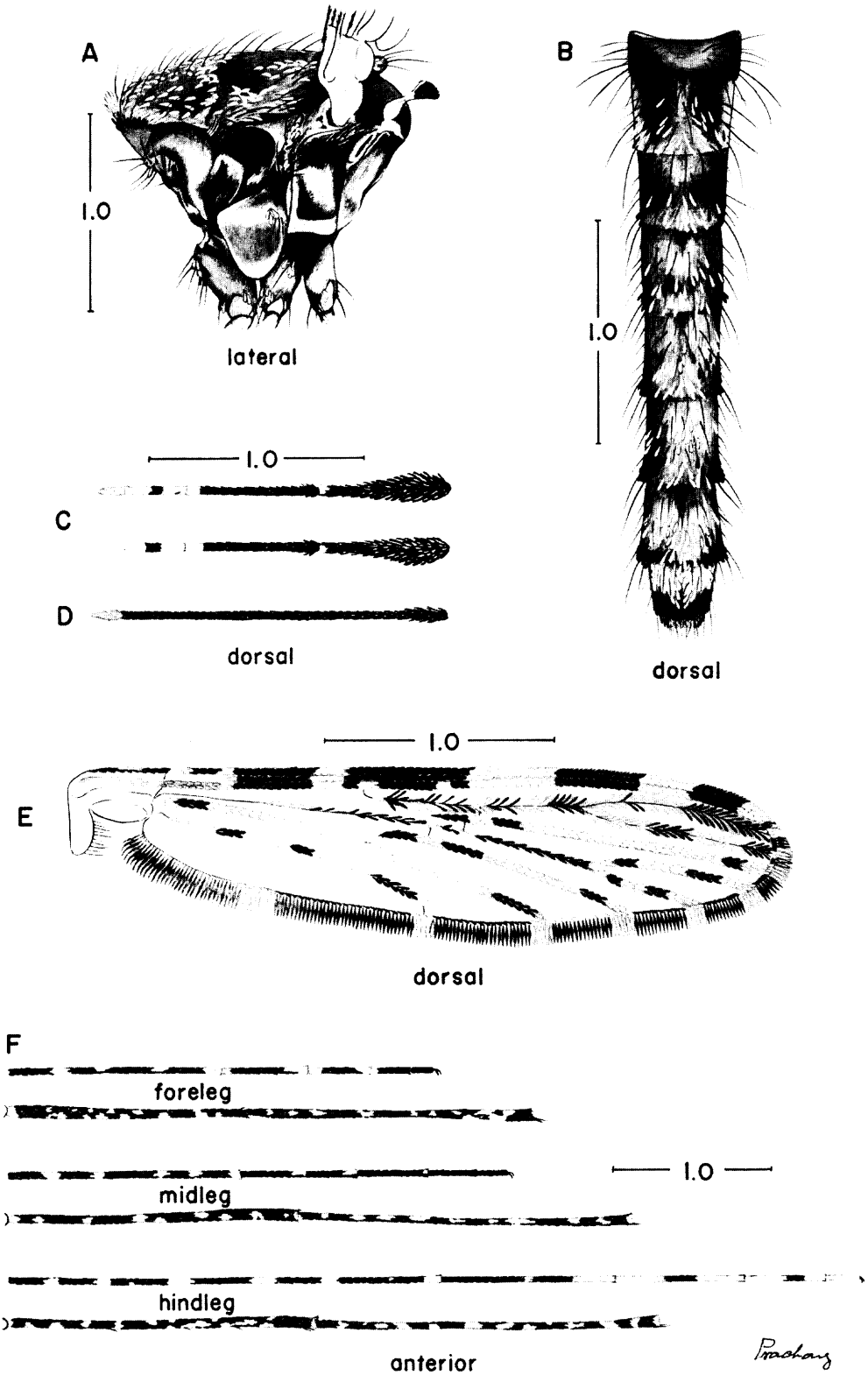
willmori

Fig. 3



sawadwongporni

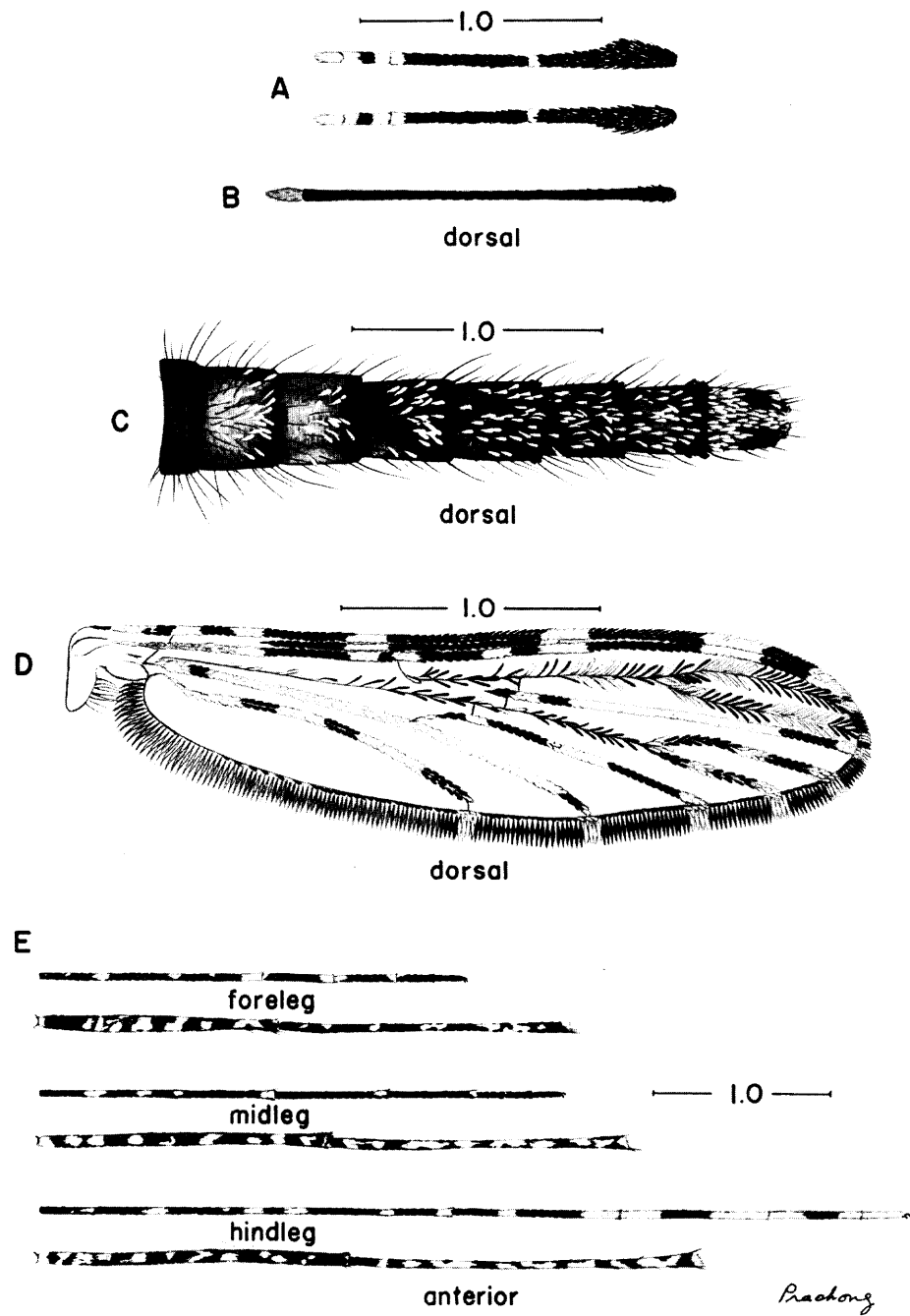
Fig. 4



*Prachay*

notanandai

Fig.5





dravidicus

Fig. 6

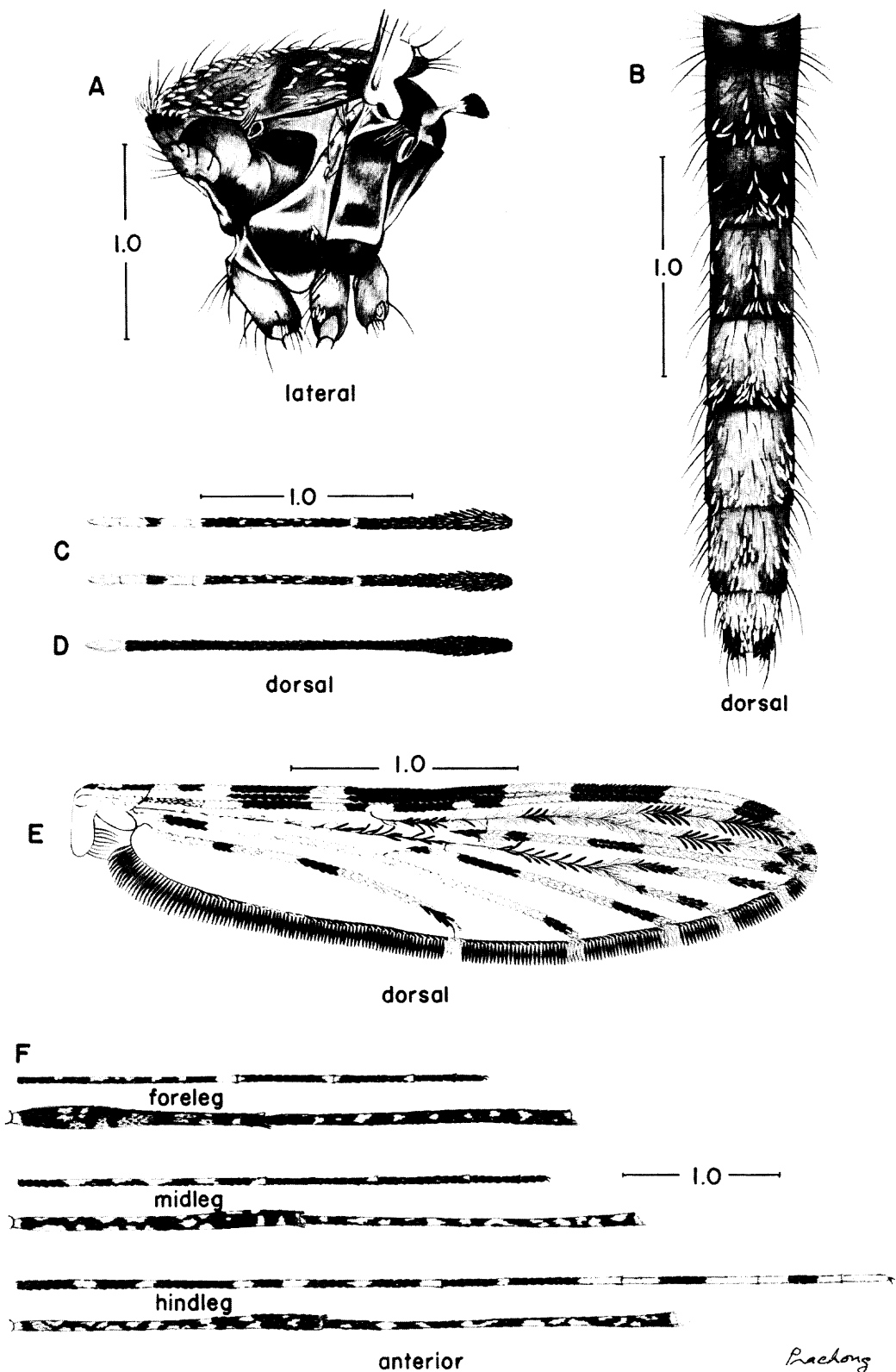
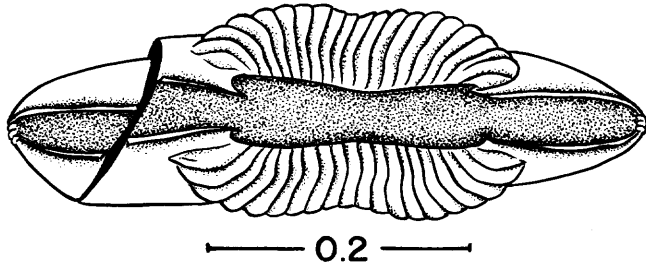
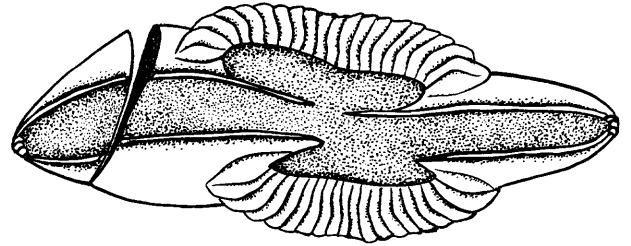
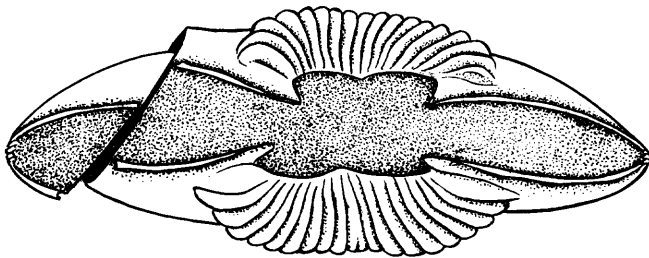
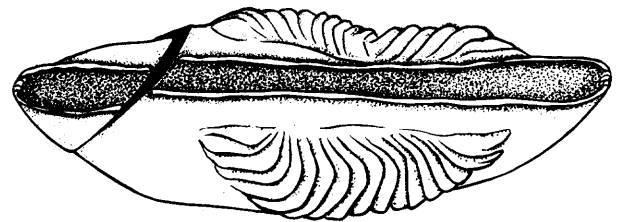
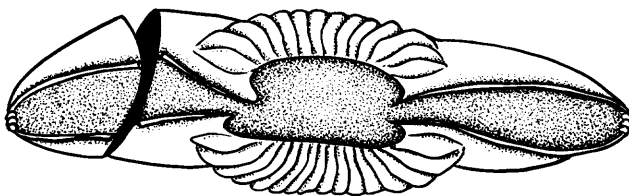
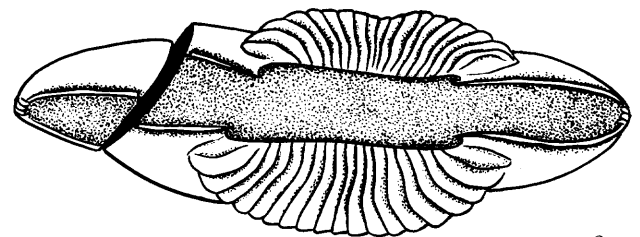


Fig. 7

**maculatus****pseudowillmori****willmori****sawadwongporni****notanandai****dravidicus**

Rampa, R.